2. REGIONAL GEOLOGY AND HYDROGEOLOGY

The available literature on the regional geology and hydrogeology of Marion County provided information for the preliminary development of the proposed tunnel corridor for the Fall Creek Evaluation Study. Detailed geotechnical information, to be obtained during a later project phase as indicated in Chapter 10 of this report, is required to further evaluate the preferred tunnel corridor and alignment along Fall Creek and White River. In addition to known geological data, information on public wells and private wells has been included based on available literature and contact with Indianapolis Water and Mundell & Associates, Inc., as requested by the City of Indianapolis Department of Public Works (DPW). The Indiana Geological Survey (IGS) and the Center for Earth and Environmental Studies at Indiana University – Purdue University Indianapolis (IUPUI) were contacted regarding geological data that was not reviewed by the project team; however, no additional data was provided.

2.1 TOPOGRAPHY

The proposed tunnel corridor is primarily located along the Fall Creek and White River in Marion County, Indiana. Marion County is located in the Central Till Plain physiographic region of Indiana (Gray, 2000), and the surface features are a product of Pleistocene continental glaciation. The County is drained to the White River and its two principal tributaries, Eagle Creek and Fall Creek, as well as other smaller tributaries such as Pogues Run and Pleasant Run. The topographic relief along the tunnel evaluation area is gently sloping downward from the northeast to the south. The total relief is approximately 60 feet, ranging from about 735 feet above mean sea level (msl) near Keystone Dam to approximately 675 feet above msl near combined sewer overflow (CSO) outfall 117. Figure 2.1 illustrates the location and topography of the tunnel evaluation area in Marion County, and includes the major tributaries to the White River.

The portion of the Central Till Plain in Marion County is divided between two physiographic subregions (Tipton Till Plain and New Castle Till Plain and Drainageways), with the northwest valley wall of the White River forming the boundary (Figure 2.2). The Tipton Till Plain is located west of the White River valley and has uniform low relief and a few low hills that were formed from the deposits of

2. REGIONAL GEOLOGY AND HYDROGEOLOGY

INSERT FIGURE 2.1

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INSERT FIGURE 2.2

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glacial ice disintegration. East of the Tipton Till Plain and separated by a network of drainage valleys is the New Castle Till Plain and Drainageways. The drainage valleys (or tunnel valleys) were incised beneath the continental ice sheets by glacial melt water. The proposed Fall Creek/White River Tunnel corridor occupies a portion of two of these tunnel valleys, the White River valley and the lower reaches of the Fall Creek valley, which contain thick fills of mostly sand and gravel.

2.2 SOILS

The soils in Marion County are thick unconsolidated deposits from three glacial ages. Dating from oldest to youngest, they are: Kansan, Illinoian, and Wisconsinan. The soils consist primarily of unconsolidated glacial and glaciofluvial sediments. Throughout most of the county, the average sediment thickness is 100 feet. However, the deposit thickness ranges from less than 15 feet to more than 300 feet. The unconsolidated deposits are generally differentiated into two formations by age, the pre-Wisconsin (Illinoian and older) Jessup Formation and the late Wisconsin Trafalgar Formation. Figure 2.3 illustrates the distribution of the surface soil (pre-Wisconsin) deposits along the tunnel evaluation area.

To the north and east in the county, these are often separated by a persistent weathering profile containing a paleosoil that was developed during the Sangamon Interglacial period. However, in the central and southwestern parts of the county, the pre-Wisconsin appears to have deeply eroded during the late Wisconsin producing a surface of widely varying age. There are no known deposits of early to middle Wisconsin age in Marion County. The Jessup Formation is generally buried under the Trafalgar Formation, and only outcrops in small areas under deeply incised streams.

The valleys of the White River and the lower reaches of Eagle Creek and Fall Creek contain a thick complex of Wisconsin and Illinoian outwash, sand, and gravel that lies on bedrock. The general stratigraphy of the deposits include the Trafalgar Formation's Cartersburg till (upper Wisconsin) covering the Center Grove till (lower Wisconsin), which overlay till sequences in the Jessup Formation of Illinoian age.

2. REGIONAL GEOLOGY AND HYDROGEOLOGY

INSERT FIGURE 2.3

The deposits consist primarily of fine grained till or till-like sediments and contain two to three relatively continuous horizons of sand and gravel between the sequences. There are three major deposits of outwash sand and gravel in Marion County (Brown et al, 2000). The three major deposits of outwash include:

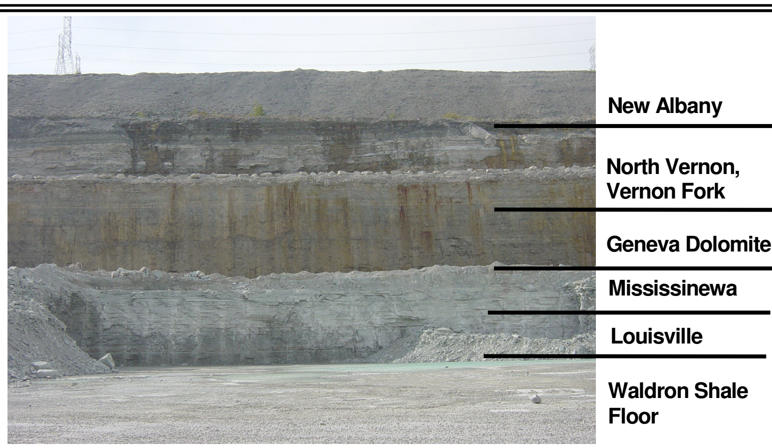
- An extensive complex of late Wisconsin outwash filling the valleys of the White River and the lower reaches of its two largest tributaries, Eagle Creek and Fall Creek
- Pre-Wisconsin outwash occupying a buried valley under the upper reaches of Fall Creek
- Pre-Wisconsin outwash consisting of two bodies flanking the White River valley in the southwest of the county

These outwash deposits are primary sources of groundwater for local wells in the shallow aquifer. The hydrogeologic setting and potentiometric surface of the shallow aquifer is described in more detail in Section 2.5.

The overburden along the proposed Fall Creek/White River Tunnel corridor consists primarily of sand and gravel. The thickness generally ranges between 65 and 80 feet in the northeast to about 120 feet in the southwest. The entire column of the deposit is sand and gravel and lies directly on bedrock except for two short sections along the proposed tunnel corridor. Between the westward projection of 21st Street and 10th Street, the sand and gravel lies on a thin, late Wisconsin till sheet resting directly on the bedrock. South of Interstate 70, the sand and gravel lies on the bedrock surface but it is intercalated with discontinuous, late Wisconsin till sheets.

2.3 BEDROCK

Marion County is located between two regional bedrock structures, the Cincinnati Arch to the northeast and the Illinois Basin to the southwest. The sedimentary rocks dip at 30 to 50 feet per mile to the southwest with the dip increasing to the southwest (Brown and Laudick, 2000). Increasingly younger formations form the bedrock surface from northeast to southwest. Relief on the bedrock surface is at least 300 feet in Marion County and is the result of pre-glacial and glacial stream erosion on the rocks of varying hardness. The lowest bedrock elevations occur in a deeply incised bedrock valley system in the Oaklandon area under the upper reaches of Fall Creek, northeast of the project tunnel corridor. The highest bedrock elevations occur in the extreme northwest and southwest corners of the county. Other than in quarries, exposed bedrock exists in the extreme southwest near the Village of Newton and along the White River in Broad Ripple. Table 2.1 lists the Marion County bedrock stratigraphy for the Devonian and Silurian carbonates, formation thicknesses at the Martin Marietta Kentucky Avenue Mine, and county-wide thickness ranges. As part of this project, B&V conducted a site visit to the Harding Street Quarry to inspect the bedrock stratigraphy for the Devonian and Silurian carbonates. The site visit memorandum, additional photographs taken during the site visit and logs of borings drilled at the quarry are included in Appendix B-1 – Harding Street Quarry Visit Memorandum and Site Photos.



Photograph from Harding Street Quarry Visit

Devonian rock, mainly dolomite and limestone, of the Muscatatuck Group underlie the northeast corner of the county except in the deeper bedrock valleys that are floored by Silurian limestone, dolomite, and argillaceous dolomite of the Wabash and Pleasant Mills Formations. The Silurian is underlain by Ordovician limestone and shale of the Maquoketa Group. The Maquoketa Group is a regional aquiclude that

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TABLE 2.1
MARION COUNTY BEDROCK STRATIGRAPHY TO THE SILURIAN SYSTEM
FALL CREEK/WHITE RIVER TUNNEL

System	Rock Units (Hasenmueller, 2003)			Description (Harrison, 1963)	Thickness at Kentucky Avenue Mine[1]	Thickness in Marion County[2]
Devonian	New Albany Formation			Deep brown to black, evenly laminated, brittle, pyritiferous shale (upper part is Mississippian, only present along southern end of Fall Creek alignment)	80 feet	97 to 155 feet, average 127 feet
Devonian	Muscatatuck Group	North Vernon Formation		Light gray, tan, and white, dense to coarse grained limestone with common chert, glauconite, and phosphate nodules	52 feet	86 to 155 feet, average 115 feet
Devonian	Muscatatuck Group	Jeffersonville Formation	Vernon Fork Member	Relatively pure limestone grading downward to laminated dolomite	65 feet	
Devonian	Muscatatuck Group	Jeffersonville Formation	Geneva Member	Light gray through tan and buff to chocolate brown dolomite and dolomitic limestone with white, crystalline calcite masses	41 feet	
Silurian	Wabash Formation		Liston Creek Member	Gray, thinly bedded, dolomitic, cherty limestone (probably pinches out north of Fall Creek Project area)	Not Present	16 to 210 feet, average 89 feet
Silurian	Wabash Formation		Mississinewa Member	Gray to blue-gray, massive calcareous shale or argillaceous limestone	54 feet	
Silurian	Pleasant Mills Formation		Louisville	Gray to buff, finely crystalline to dense, dolomitic limestone with abundant corals	46 to 52 feet	28 to 88 feet, average 53 feet
Silurian	Pleasant Mills Formation		Waldron Member	Varies from very soft, light greenish gray to bluish, fragile clay shale to a calcareous knotty shale	1 to 3 feet	
Silurian	Salamonie Formation			Pale tan to tan and gray, thinly bedded, dolomitic limestone and grading downward to dense limestone containing two beds of light gray shale and chert	55 feet	NA
Silurian	Brassfield/Sexton Creek			Salmon-colored, crystalline, unbedded limestone	Not Exposed	NA

Notes:
(1) Thickness of rock units as provided by Martin Marietta Corp. at the Kentucky Avenue Mine
(2) Thickness of rock units in Marion County area (Hasenmueller, 2003)

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forms the base for the local bedrock groundwater aquifer system in the Devonian and Silurian carbonate sequence.

Southeast of the Muscatatuck Group, a broad band of shale belonging to the New Albany Formation forms the bedrock surface. The shale of the New Albany Formation has eroded to a surface of relatively gentle relief and the unit forms a groundwater-confining layer where it overlies the Devonian and Silurian carbonates. The Rockford Formation, which is a thin, impure limestone, overlies the New Albany Formation in southwest Marion County. The Rockford Formation is rarely more than 10 feet thick and is generally not shown on bedrock geology maps. This formation is not known to be present in the project area. In the extreme southwest corner of the county, the Mississippian Borden Group forms the bedrock surface. The bedrock surface is mainly shale of the New Providence Formation. Local bedrock knobs capped by sandstone of the overlying Spickert Knob Formation rise above the shale to produce a bedrock surface relief of about 150 feet.

Devonian and Silurian carbonate rock underlie most of Indianapolis, the valleys of the White River and the lower reaches of Fall Creek, which includes the proposed Fall Creek/White River Tunnel corridor. The formations, with an aggregate thickness of nearly 300 feet, include in descending order the North Vernon Limestone; the Jeffersonville Limestone; the Wabash Formation consisting of dolomitic limestone and shale members; the Pleasant Mills Formation; the Salamonie Dolomite; and the Brassfield Limestone. At the extreme southern end of the project corridor, the Devonian carbonates are overlain by shale of the New Albany Formation.

The North Vernon and Jeffersonville Formations of the Muscatatuck Group are not easily differentiated. The North Vernon Formation is fine to coarse grained limestone. The Jeffersonville Formation consists of two members, the Vernon Fork Limestone and Geneva Dolomite. In older boring logs, the North Vernon and Jeffersonville Formations are not differentiated often and are referred to collectively as the “Corniferous Limestone” (Hasenmueller, 2003).

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The contact between the Devonian Geneva Dolomite and the underlying Silurian Wabash Formation is a regional unconformity. Large, complex reef structures developed during the Silurian stood as mounds above the sea floor during deposition of the later Silurian and Devonian carbonates. The reef complexes can locally disrupt the normal succession of the Silurian strata and protrude up into the Devonian strata, thus reducing their thickness or even replacing them.

The Wabash Formation is comprised of two irregularly developed members, Liston Creek and Mississinewa. The Liston Creek member is a cherty dolomitic limestone and the Mississinewa consists of calcareous shale and argillaceous limestone. Underlying the Wabash Formation is the Pleasant Mills Formation, which is comprised of the Louisville Dolomitic Limestone and the underlying Waldron Shale. The lowest Silurian formation is the Salamonie Dolomite that is sometimes differentiated into the Salamonie and overlying Limberlost formations.

As previously described and shown on Figure 2.4, the bedrock surface along the proposed Fall Creek/White River Tunnel corridor is developed on the Devonian carbonates except for the extreme southern end. It generally rests at an approximate elevation of 650 feet msl north of 35th Street and slopes to about 600 feet msl just north of 29th Street, where the elevation remains relatively constant to the southern end of the proposed tunnel corridor. Although more prevalent in southwestern Indiana, it is generally accepted that because of the relatively high yields from bedrock wells, this surface has been subjected to the solution activity of groundwater. It has resulted in open joints and other karstic features in the upper 100 feet of bedrock in the area along the proposed corridor. At the far southern end of the proposed corridor, south of Raymond Street, the Devonian carbonates are overlain by a thin section of the New Albany shale, but the karst features are known to be developed for some distance under the New Albany. Figure 2.5 is an illustration of a preliminary geologic profile along the proposed corridor that was developed based on existing geological boring and well log data. The actual geologic profile for the project should be developed using data from future geotechnical investigations.

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Insert figure 2.4

2. REGIONAL GEOLOGY AND HYDROGEOLOGY

Insert figure 2.5

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2.4 SEISMIC ZONE CONSIDERATIONS

The City of Indianapolis falls within the Environmental Protection Agency (EPA) defined seismic impact zone due to the thickness of the soils that could result in amplification of earthquake shaking (Eggert, 1995). Several paleoseismic studies have been previously completed to document major prehistoric earthquakes, which have generally occurred in the Wabash Valley and southeastern Indiana. However, a report completed in 1995 on Indiana's seismic risk concluded that additional geotechnical and hydrologic data is needed to better define the future risk of liquefaction in central and southern Indiana (Eggert, 1995). Considering that no past indications of earthquake liquefaction features have been confirmed for Indianapolis, specialized seismic zone building codes are not currently required for construction.

The only mapped fault in the project area is the Fortville Fault. This normal fault (all known faults in Indiana are "normal") is located east of and within six miles of the proposed corridor. It is not known to be part of any active fault system. While no faults or shear zones are mapped along the proposed corridor, it is possible that minor faults and shear zones occur in the bedrock. Where they occur, enhanced solution activity in these zones of weakness may produce solution openings and karst features that will be conduits for seepage into any bedrock tunnel if intersected.

2.5 HYDROGEOLOGY

Several aquifer systems produce groundwater in Marion County wells. Water level data from wells, piezometers, and subsurface geology indicate that sand and gravel deposits at and above the pre-Wisconsin surface constitute a shallow aquifer (Brown et al, 2000). The shallow aquifer is generally confined in the upland areas and unconfined in the valleys of the White River and the lower reaches of Eagle and Fall Creeks. Below this are three generally confined aquifer systems, corresponding to the three relatively continuous horizons of sand and gravel in the pre-Wisconsin deposits, and the bedrock aquifer system (Meyer et al, 1975). In general, these aquifer systems are directly connected along the project corridor. To a limited extent, they may locally function as independent systems separated by cohesive fine

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grained till and till-like deposits. Figure 2.6 shows the hydrogeologic setting of the outwash deposits, and the potentiometric surface of the shallow aquifer for Marion County.

The most productive aquifers in Marion County are the three major deposits or complexes of outwash sand and gravel. The most prolific of these is part of the shallow aquifer system occupying the valleys of the White River and the lower reaches of Eagle Creek and Fall Creek. It consists of late Wisconsin outwash, resting on bedrock or locally a thin, late Wisconsin till sheet that directly overlies bedrock. In Marion County the thickness of the unconfined aquifer complex can be as much as 200 feet and is generally thought to range between 65 and 120 feet along the proposed Fall Creek/White River Tunnel corridor.

Two other major aquifer complexes occur as parts of the three pre-Wisconsin confined sand and gravel aquifer systems. In the buried bedrock valley beneath the upper reaches of Fall Creek, the three confined horizons of sand and gravel coalesce into a mass of outwash as much as 150 feet thick. The gorge of Fall Creek was incised through the overlying late Wisconsin till-like deposits into the pre-Wisconsin aquifer complex and then partly filled with late Wisconsin outwash creating a means for rapid recharge.

The middle Illinoian sand and gravel horizon thickens to between 15 and 30 feet adjacent to and on either side of the White River valley in southwestern Marion County. This southwestern aquifer complex appears to be the remnants of former outwash plains that graded into the ancient White River valley during middle Illinoian time. Both the Fall Creek and southwestern aquifer complexes are the primary contributors of groundwater to wells in their respective areas.

The Devonian and Silurian carbonate formations constitute the bedrock aquifer system in Marion County. Based on the well logs reviewed, hydrogeologists typically refer to the carbonate formations collectively as the “Silurian and Devonian Carbonate Aquifer System”. From a hydrogeologic perspective, these two carbonate formations behave similarly and therefore are typically grouped together, but can be

2. REGIONAL GEOLOGY AND HYDROGEOLOGY

INSERT FIGURE 2.6

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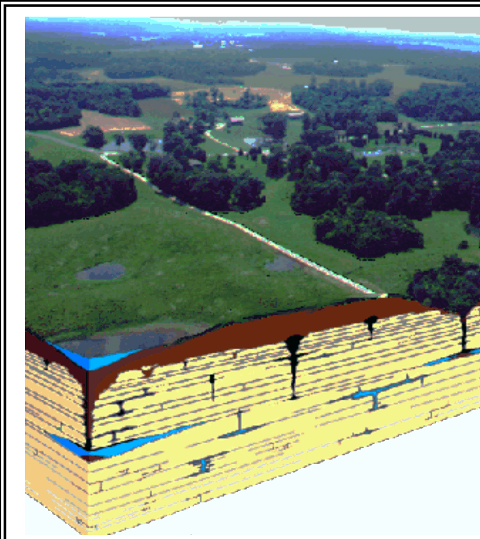
distinguished from one another upon further inspection. Shale of the Ordovician Maquoketa forms the base of the system. It is generally confined by overlying glacial drift in the northeastern part of the county and by the New Albany shale in the southwest and western parts of the county. It is not confined along most of the proposed Fall Creek/White River Tunnel corridor where it is in contact with permeable outwash deposits.

The rock is well jointed, but the productivity of the aquifer system varies greatly depending on the extent of solution activity. The rock currently overlain by drift was subject to solution activity before the drift was deposited. The solution activity opened joints and produced karst features in the upper 100 feet of rock, which increased the aquifer transmissivity. The rock overlain by shale had retarded solution activity. The shale also restricts the downward percolation of recharge. The bedrock aquifer is most productive where it is in contact with the glacial outwash complex occupying the valleys of the White River and the lower reaches of Eagle and Fall Creeks. Recharge is greatly accelerated by the rapid percolation of water through the outwash (Hartke et al, 1980). In this area, individual wells can commonly produce several hundreds of gallons per minute from the bedrock.



Pictorial Representation of Karst Geology

The proposed Fall Creek/White River Tunnel corridor is located in a geological environment that is capable of producing large amounts of groundwater. By studying local well yields, (Meyer et al, 1975) estimated that the outwash has hydraulic conductivities ranging from 40 to 415 feet per day (10^{-2} to 10^{-1} centimeters per second). The potentiometric surface along the proposed corridor is shallow, ranging from an approximate elevation of 700 feet msl in the northeast to about elevation 670 feet msl at the south end. This corresponds to an estimated depth to groundwater of 15 to 25 feet adjacent to the floodplains along the proposed tunnel corridor. This prolific aquifer is in direct contact with bedrock that has been subjected to solution by groundwater producing karstic features down to about 100 feet below the top of rock, with the exception of a short section between about the western projection of 21st Street and 10th Street. Groundwater inflow will be a concern during construction of a tunnel in either the overburden or bedrock. Groundwater considerations during the geotechnical exploration program are discussed further in Chapter 10.

2.5.1 City Well Fields

As the proposed corridor of the Fall Creek/White River Tunnel extends to the most northern CSO outfall on Fall Creek, it begins in one of Indianapolis' municipal water supply well fields and passes through another. The Fall Creek well field, with wells ranging in depth from 80 to 360 feet, is in the vicinity of the State Fairgrounds at the northeast end of the proposed corridor. The proposed corridor also runs through the Riverside-White River well field located at the confluence of Fall Creek with the White River. The wells in the Riverside-White River well field vary between 180 to 416 feet in depth. The two well fields have production capacities, using wells producing from both the bedrock and overburden, of 9.5 and 25.4 million gallons per day (mgd), respectively. Figure 2.7 shows the geographic distribution of the City's well fields in relation to the proposed tunnel corridor along the White River and Fall Creek. Registered information on wells in the tunnel evaluation area and electronic data showing reviewed municipal well logs is included in Appendix B-2 – Summary of Well Information Provided by Mundell and Associates. Production well information for the City's wells is presented in Appendix B-3 – Indianapolis Water Production Well Information.

There are potential impacts to the City's well fields during future construction of the selected tunnel corridor. Construction techniques, such as pre-excavation grouting, can be employed to mitigate the effects of groundwater table drawdown during shaft and tunnel construction near the well fields. Factors related to groundwater impacts were considered during the decision screening process, which is described in Section 15 – Decision Screening.

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Insert Figure 2.7

2. REGIONAL GEOLOGY AND HYDROGEOLOGY

2.5.2 Private Wells

As shown in Figure 2.7, there are several high capacity private wells located along the proposed tunnel corridor. Several moderate to high volume groundwater users in the tunnel evaluation area are indicated on Figure 2.7, and include the National Starch Company, Eli Lilly, Hebrew National, IUPUI, and American United Life. As with any tunneling project, impacts to wells need to be considered during the design phase of the project after sufficient hydrogeologic and hydraulic field data has been collected. Construction techniques, such as pre-excavation grouting, can be employed to reduce groundwater inflows during tunnel construction and is not anticipated to impact groundwater quality. Factors related to private well impacts near the proposed tunnel corridor were considered during the decision screening process, which is described in Appendix J – Decision Screening Process Data. Appendix B-2 – Summary of Well Information Provided by Mundell and Associates includes a list of all of the wells within the project area and an electronic file of their well logs.